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Hazard Identification and Risk Analysis system to minimize the Impacts of shipping on marine environment

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Abstract: Shipping has been a historic business in which safety has been a concern for hundreds of years. The MARPOL conventions were established in the 1970s in response to growing public concern about the destructive repercussions of marine pollution due to multiple oil tanker accidents. Hazard identification and risk analysis (HIRA) begins with the process design and continues through the discharge and decommissioning of the containers. Furthermore, the issue continues, and the active pollution generating phase will not be completed until the crash, and missing containers at sea are no longer a threat. This can be recovered by reducing shipping's negative effects on the maritime environment using a hazard identification and risk assessment approach. The X-Press Pearl incident in Sri Lanka will be discussed in this study, how the country recovers, and the method of hazard identification and risk assessment should be implemented.

Index Terms: Hazard Identification, Marine Pollution, Marine Shipping Risk Assessment.

1. Introduction

Shipping has been a historic business in which safety has been a concern for hundreds of years. Meanwhile, incidents have frequently resulted in acknowledging the necessity for risk controlling measures at sea. The capsizing of the liner Andrea Doria spurred a US delegation to attend the 1960 International Safety Conference. They proposed the concept of measuring ship safety by the amount of damage a ship can withstand [1]. The MARPOL conventions were established in the 1970s in response to growing public concern about the destructive repercussions of marine pollution due to multiple oil tanker accidents [2]. Following the Exxon Valdez catastrophe in 1990, the International Maritime Organization (IMO) mandated the use of double-hull tankers. These tragedies highlight the ongoing need for contemporary risk assessment procedures to be implemented in the commercial shipping industry.

The United Kingdom suggested to the International Maritime Organization (IMO) in 1993 a specific sort of risk management framework known as the Formal Safety Assessment (FSA). Since then, the FSA has been a top priority on the IMO's Maritime Safety Committee's agenda. In 1997 (IMO, 1997) and 2001, the IMO used the FSA process to produce interim guidelines. FSA is a tool meant to help maritime regulators. It is not intended to be applied to specific ships but rather to be used in a generic way for all shipping [3].

The operational procedure completely changes when it comes to chemical and hazardous container shipping. To limit the effects of shipping on the marine environment, hazards of a process, such as inherent reactivity, flammability, and toxicity of raw materials, intermediates, products, and catalysts, must be maintained through hazard identification and risk analysis systems. During process development, the risk caused by proposed processing stages must be calculated based on knowledge of inherent hazards and possible controls. Hazard identification and risk analysis (HIRA) starts with the process design and continues until the containers are discharged and decommissioned.

The X-Press Pearl incident is considered Sri Lanka's worst maritime disaster to date [2]. It has wreaked havoc on Sri Lanka's delicate coastline ecology, local populations, and economy. Furthermore, the incident is still unfolding, and the active pollution creation phase will not only be completed after the hazards from the wreck and missing containers at sea are eliminated. The incident's complexity arises from the variety of pollutants involved – oil, dangerous chemicals, and plastics – and the lack of information regarding the nature and status of a significant portion of the vessel's cargo. Furthermore, the plastic spill's expanding the geographic scope - the greatest on record - is projected to have Tran's boundary consequences, exacerbating the crisis. There were three immediate concerns associated with the incident that must be addressed as quickly as possible:

- A massive fuel oil spill aboard the ship.
- Pollution and navigational hazards caused by the crash and lost containers.
- Pollution and navigational hazards caused by the wreck and lost containers.

To mitigate these hazards, proactive and diligent surveillance is essential. Key actors are now reasonably well prepared to cope with an oil spill, thanks to the creation of offshore and coastline clean-up strategies, as well as the deployment of response equipment. As soon as conditions permit, action should be made to contain and recover the limited but continual discharge of oil from the wreck. Similarly, immediate planning for the removal of the crash lost containers and debris is required. This massive decommissioning project requires a precise strategy to be prepared promptly, in a participatory and transparent manner, and irrespective of present concerns about monsoon-related weather issues [4]. Government-sanctioned control is essential for ensuring accountability for the work's acceptable completion and public trust in the crash and debris recovery process. The authorities in Sri Lanka are carrying out a special and effective clean-up operation following the plastic spill. However, in order to improve its effectiveness, certain critical activities must be taken, including:
Contamination examination of the plastic trash to evaluate whether it is harmful;

- Refinement and scaling-up clean-up processes to reduce sand abstraction and recover small charred particles;
- Establish technological criteria for completing micro plastic clean-up procedures while reducing environmental damage inadvertently.

The incident's environmental assessment focus should be on pollution 'hot spots,' such as the wreckage area and impacted coastline areas. The research strategy should be aimed at answering several fundamental questions with major socioeconomic ramifications and assuaging public concerns, including:

- Is it safe to eat the fish caught inside or outside the declared 'no fishing area'?
- When should the fishing moratorium be lifted?
- Is there a link between the incident and the documented increase in turtle and marine mammal deaths?

A biomonitoring program is suggested as a very easy and cost-effective way to monitor the condition near the wreck and the status of vulnerable marine ecosystems (such as coral reefs) in the incident region. While significant sampling has been done, it is now critical to concentrate the analysis on essential factors and hasten laboratory testing to obtain scientific data for decision-making and quantify the incident's actual harm. The findings should also aid in the development of a longer-term marine environment monitoring program. This is critical for tracking the disaster's environmental consequences and gaining insight into baseline conditions, which are necessary for performing scientific assessments and remediation of similar marine events. For litigation and damage and loss assessments, a solid knowledge basis is also essential.

Beyond immediate corrective efforts, the ultimate goal for Sri Lanka is to emerge from this horrific experience with a more resilient system for preventing and responding to future marine disasters. This would necessitate a multi-year project that would contain the following elements:

- Creation of a maritime disaster plan
- A capacity-building and training program
- Enhancing the institutional foundation for its implementation.

A large-scale project like this relies on the formation of a solidarity coalition between the Sri Lankan government and its international allies and partners. The need for a designated mechanism to mobilize international support is underscored by the fact that success will ultimately depend on coordinated action by varied players. As a result, Sri Lanka's efforts to solidify its position as a worldwide maritime and logistical hub will be bolstered, while ocean health, fisheries resources, and global trade will be better protected. When considering the organisms that we have to investigate for possible impact, you can get a clear idea of what we are going through as scientists.

The Sri Lankan Ocean, being a biodiversity hotspot, is home to hundreds of living organisms, including fish, mollusks, crustaceans, mammals, turtles, and many others. We are doing our best to scientifically analyze the samples we acquire from these creatures despite our limited physical and human resources. Apart from that, people must pay attention to the microorganisms that live in this area. Because, despite their small size, they play a significant role in food chains in those ecosystems. Planktons, eggs and larvae of numerous fish species and a variety of other microorganisms are among them. This is not a minor cleaning issue; it is a significant environmental issue. This can be recovered by employing a hazard identification and risk assessment approach to reduce shipping's negative effects on the marine environment.

2. HAZARD IDENTIFICATION

Hazard means "anything that can potentially cause harm, including injury, disease, death, environmental damage, property and equipment damage.” Moreover, it can be defined as "the set of conditions of a system that, together with other conditions in the system’s environment, will inevitably lead to an accident." Hazards of shipping on the marine environment are very critical cause to the identification. Shipping in marine environment generally uses ships and boats. ship hazard characteristic is that it is more difficult to achieve ideal levels of separation from the onboard hazards, since command and control facilities, living/working areas, fuel, propulsion, power generation plants, and emergency systems are within the ship. Another characteristic of ship hazards is that the ship could experience different kinds of hazards at different phases of the operation.

Hazard identification of shipping in a marine environment should be performed with selected professionals. Propose hazard identification should identify all conceivable and relevant hazards to the cause. Usually, a team will have 6-10 experts, including naval architects, structural engineers, machinery engineers, surveyors, human factor engineers, marine officers, and meeting moderators, provide the necessary expertise for the topic under study.

Identification of hazards is used historical incidents as a reference database. With the identification, it should be ranked by order to risk levels. Prioritizing the hazards helps to identify what hazards are high risk and low. With that, it can use for more analysis.

What-If analysis can be used for identifying hazards and possible accidents, qualitatively evaluate the consequences and determine the adequacy of safety levels. What if analysis include several steps;

1. Team Kickoff
2. Generate What-if Questions

   Generates possible What-if questions relating to each step of the experimental procedure and each component to determine sources of issues and failures of the system.

   Some factors to be considered when developing the questions;

   - Potential human error
   - Equipment component failures
   - Critical parameters (temperature, pressure, time, and flow rate)

3. Evaluate and Assess Risk
4. Develop Recommendations
5. Prioritize and Summarize Analysis
6. Assign Follow-up Action

A checklist is also an effective method to identify hazards on shipping in a marine environment. The checklist is a document that includes a number of information list that gives a general guideline for manage and identifying hazards and issues. In shipping, there can be prepared daily checklists, weekly checklists, working area checklists, and every place that will make hazards on ships. The checklist is primary method of hazard identification, and it can be use efficiently on Shipping in marine. Moreover, Hazard and operability studies (HAZOP) /Failure Mode and Effect Analysis and many more methods are available for Hazard identification. Several common hazards can be identified by referring to historical incidents and what-if analysis of shipping hazards in a marine environment.

- Collision and grounding
- Fire
- Explosion
- structural integrity failures
- Loss of power
- Hazardous material
- Loading Failures
- Extreme environmental conditions

Collision and grounding

The collision occurs when a ship strikes another ship or another object. It is a high consequence and low probability hazard for oceangoing ships. Grounding occurs when the ship bottom is penetrated by the sea bottom or by underwater rocks. Fig.1 shows collision and grounding ships in a marine environment.

Fig. 1 collision and grounding ships

Fire

Firing is a serious case on shipping in a marine environment. Fire is a ship hazard of higher consequence. It is estimated that more than a third of all shipboard deaths during the period 1987-1992 were due to fire accidents[5]. To decrease fire hazard, ships can be made with fire detections/fire alarms, provide guidelines to stop fires for ship crew before transportation startup, and be ready with a firefighter for fire control. Express pearl incident also fire accident happens on Sri Lankan coastal area in 2021. Due to that, Sri Lankan people faced huge consequences, so Firing is one of the worst cases on marine shipping. Fig 2. shows express pearl incident firing ship

Fig. 2. Express pearl incident Ship Firing

Explosion

Several explosions that occurred in the past were initiated on crude carrier ships. a number of explosion accidents actually happen from mistakes and violations in the operational procedure like smoke, shortcut in the procedure, etc

structural integrity failures

Failure of structural integrity occurs with faulty design, construction maintenance or operational factors. These failures cannot be identified due to impossible inspects and cannot measure structural members' conditions ships. These properties change with loading and corrosions.

Loss of power

Losing engine power is very dangerous. Without power steering, the ship becomes impossible, which causes to make many more hazardous things. Power failures occurs with mechanical failure of the engine, generator breakdown, a boiler or crankcase explosion, engine room fire, etc.

Hazardous Material

Cargos with hazardous materials like crude oils/chemicals/liquefied gases should be identified as a hazard for marine environments. In the 1986-1991 period reported 151 accidents of marine transportation of dangerous goods based on historical data[6].

3. RISK ASSESSMENT

A risk assessment aims to evaluate hazards, then remove that hazard or minimize its risk level by adding control measures, as necessary.

Before beginning a risk assessment, the safety officer must establish the proper context, including

- Scope – the extent or lifecycle of the thing, process, or operation, including the physical work area and the types of hazards assessed.
- Parameters – the scales used to assess the process, such as
  - Probability of occurrence (e.g., rare/unlikely/possible/likely/certain)
  - Severity of occurrence (e.g., insignificant/minor/moderate/major/catastrophic)
- Stakeholders – those involved in the risk assessment, including those who are internal and external to the process.
- Risk criteria – a definition of the situations that require further risk reduction to improve worker protection. The requirements must be derived from applicable legislation and include input from the relevant stakeholders [7] .

Risk Assessment steps

- Identification of hazards
- Elimination of hazards
- Analysis of risks of the remaining hazards
- Evaluation of risks of the remaining hazards

Elimination of hazards

Once hazards have been identified, the preferred means of control is eliminating the hazard. Only once hazards have been identified can action be taken to eliminate them. For a risk assessment, it is assumed that when the hazard, or combination of hazards, is present, harm to a worker will eventually occur if measures are not taken to eliminate or further control the hazards. While the safety officer should strive to eliminate hazards to provide the most significant protection from harm, this is not always possible or reasonable. The acceptable risk level is determined by analyzing, then evaluating, risks. The safety officer can identify and then apply the appropriate controls to mitigate the hazard from this evaluation.

Analysis of risks of the remaining hazards

Risk analysis is the process of developing an understanding of the risk that helps to improve and focus the evaluation of the risk. The safety officer will likely identify multiple hazards; therefore, the risk of harm should be prioritized by identifying the risks that have the most significant potential for damage and are likely to occur most frequently. The supervisor should always prioritize action on situations involving dangerous circumstances, with work suspended until interim (or permanent) controls can be implemented.

The risk analysis should include:

- A description of the hazard or the hazardous situation
- The interaction methods, including the circumstances under which interaction with the hazard, can occur. The safety officer can determine this by reviewing anticipated worker tasks, procedures, incident history, conducting observation tours, consulting with operators and other workers, etc.
- The frequency and conditions of exposure to the hazard
- The severity of a potential exposure
- The duration of exposure to the hazard
- The environment in which the work is conducted
- The education and training workers have received
- The method in which a reasonable person would react in a particular situation

It is important to remember that the assessment must consider not only the current state but also any potential situations. The hazards and risks should be documented, as an example included below (Table 1):

Table 1. Risk Documentation

Task	Hazard	Risk	Probability	Severity	Risk Level
Delivering products to customers	Drivers work alone	Maybe unable to call for help if needed	2	3	6
	Driver occasionally have to work long hours	Fatigue, short rest time between shifts	3	4	12

Risk Evaluation

Once risks have been analyzed and estimated, the supervisor can conduct a risk evaluation. The risk evaluation aims to formalize decisions about whether a particular work activity should be conducted, which risks needs to be further controlled, and the priority for addressing the risks. The treatment of risks may fit into one of four categories:

- Avoidance – taking action to exit (or avoid) the activity that gives rise to the risks.
- Reduction – reducing the risk probability, consequence, or both.
- Transfer – reducing risk probability or consequence by transferring or sharing a portion of the risk.
- Acceptance – taking no action to affect probability or consequence.

The evaluation decision must be based on the individual situation, including the available risk controls. Fig. 3 shows Risk Evaluation scale [8].

Likelihood		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Fig. 3.Risk evaluation scale

4. Conclusion

The shipping industry is the backbone of globalization and international trade. Seaborne transportation plays a major role in the world's industries and society, enabling the transport of large volumes of raw and processed material and food, water, and technological products.

The outcomes of any risk assessment are dependent on data as well as judgment in interpreting the data and anticipating industry trends, the impact of technological advances, the potential for future incidents, and so on. As a result, the results of an FSA research are contingent on both the availability of relevant data and the capacity of skilled analysts to make sensible decisions. However, to protect the marine environment, this is critical. Sri Lanka must also develop a Hazard Identification and Risk Analysis system to reduce the impact of shipping on the maritime ecosystem, including occurrences like the X-press pearl. The data determine an FSA's quality; it contains the knowledge it employs and the mathematical models it employs. Collecting and understanding risk data is fraught with difficulties. When it is discovered that data has not been recorded in many situations, the subjectivity of the FSA based on insufficient information is a major concern. A review of required and current databases relevant to marine risk assessments and the development and implementation of a plan for the systematic collecting of additional data is required.

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